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USE OF INSPIRATORY MINUTE VOLUMES IN EVALUATION OF ROTARY AND FIXED WING PILOT WORKLOAD

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Inspiratory minute volume (IMV) measurements by Mueller Respirometer were utilized in the evaluation of US Army aircrew workload and stress in helicopter and fixed wing aircraft. The IMV data obtained demonstrates a significant stress and/or workload level of the aviator in performance of helicopter day nap-of-the-earth (NOE), night nap-of-the-earth (NNOE) and with the use of night vision devices (NVD). IMV of 20.05 to 38.11 liters per minute NTPD were

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obtained during the performance of these combat operational techniques. IMV determination in-flight is considered a valuable clinical tool in the assessment of aircrew stress and/or workload.

SUMMARY

The US Army helicopter and fixed wing aircrewman is required to utilize advanced operational flight concepts for the modern battlefield such as nap-of-the-earth (NOE) and night nap-of-the-earth (NNOE) techniques and night vision devices (NVD). These techniques have increased the stress/workload level for the aircrewman. To clinically assess these effects during actual flight operations, simple monitoring techniques are required. The use of inspiratory minute volume (IMV) determinations was selected. The data collected defined the aircrewman's perception of the type aircraft and the threat of operational flight requirement. Additionally, the data supports studies by the US Army Aeromedical Research Laboratory (USAARL) to define accurate oxygen design standards. IMV was demonstrated to be increased threefold under NOE, NNOE and with the use of NVD. Refinement of the technique with the addition of other physiologic and biochemical data collection is ongoing.

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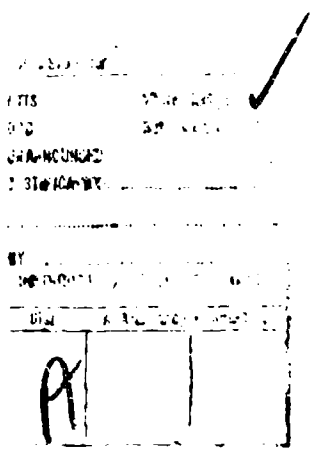

USE OF INSPIRATORY MINUTE VOLUMES IN EVALUATION OF ROTARY AND FIXED WING PILOT WORKLOAD

BACKGROUND

The operational employment of US Army helicopters and fixed wing aircraft in the high intensity air defense environment has required the development of advanced flying techniques. Day nap-of-the-earth (NOE), night nap-of-the-earth (NNOE), and night vision devices (NVD) have added markedly to the workload of the aircrew.

During oxygen utilization studies, analysis of inspiratory minute volume (IMV) data indicated significant trends dependent on flight profiles. To further evaluate this method as an indirect and simple modality in the assessment of stress and workload, a study of IMV during varied helicopter and fixed wing aircraft flight profiles was undertaken. The term IMV is utilized for simplicity in place of the usual pulmonary function notation $\dot{V}_I$.

MATERIALS AND METHODS

Data was obtained from a series of 135 flights of OH-58, UH-1H, and AH-1 helicopters and U-21 and C-7 fixed wing aircraft. Four phases of the flight were evaluated--runup (R.U.), takeoff (T.O.), cruise (C), and final approach (F.A.). The helicopter flight profile was evaluated under normal flight, NOE, NNOE, and NVD. Thirty (30) subjects wore standard US Army A-13A oxygen masks connected to a portable Mueller respirometer. Photograph A illustrates the respirometer and A-13A oxygen mask worn ambulatory prior to flight. Photograph B demonstrates the position of respirometer and hose for the aircrewmember. Inspiratory minute volumes obtained in liters per minute (LPM) were corrected to NTPD, normal temperature (70°F), pressure (760 Torr), and dry. Barometric pressure was obtained by on-board barometer accurate to 0.5 Torr. The volume of inspired air was measured throughout the period of time in each phase of flight. The longer phases are cruise and during NOE, NNOE, and NVD. The minimum period for any sample was 10 minutes. Temperature of inspired air was determined by standard thermometer intrinisic to the Mueller respirometer.

RESULTS

Fixed Wing Data (U-21, C-7). The IMV data from evaluation of fixed wing flight profiles is provided in Table I.

PHOTO A

PHOTO C

TABLE I

FIXED WING INSPIRATORY MINUTE VOLUME (NTPD)

U-21

Flight Condition		R.U.	T.O.	C.	F.A.
NORMAL FLIGHT	Mean	6.82	10.21	8.19	14.19
	S.D.	2.44	0.93	3.36	9.30
	Range	5.10-8.55	9.65-10.77	3.63-12.79	3.11-34.06

C-7

Flight Condition		R.U.	T.O.	C.	F.A.
NORMAL FLIGHT	Mean	3.33	9.76	8.25	19.12
	S.D.	---	---	0.32	---
	Range	---	---	8.06-8.51	---

NOTE: R.U. = Run-Up
T.O. = Take Off
C = Cruise
F.A. = Final Approach
S.D. = Standard Deviation

Table I demonstrates the IMV response to the flight profile. Of note is the increased IMV at takeoff and final approach for fixed wing aviators.

Rotary Wing Data (OH-58, UH-1H, AH-1). The IMV data from flights of three helicopter types under four mission profiles is shown in Table II.

DISCUSSION

The rotary wing IMV demonstrates the aviator's perception of his aircraft and mission profile threat. The highest threats perceived are the nap-of-the-earth profiles and the night vision devices.

TABLE II

ROTARY WING INSPIRATORY MINUTE VOLUMES (LPM, NTPD)

UH-1H

Flight Condition		R.U.	T.O.	C	T	F.A.
ROUTINE	Mean	---	11.59	10.95	---	10.72
	S.D.	---	0.75	0.47	---	3.24
	Range	---	11.06-12.12	10.48-11.42	---	7.04-13.14
NOE	Mean	---	12.61	16.23	20.05	7.71
	S.D.	---	10.12	2.69	0.98	1.87
	Range	---	1.11-25.37	14.81-22.22	17.56-21.41	8.15-10.45
NNOE	Mean	---	---	11.88	21.45	17.20
	S.D.	---	---	2.13	7.054	1.75
	Range	---	---	9.44-14.16	13.15-32.66	15.96-18.94
NVD	Mean	---	18.20	---	34.51	38.11
	S.D.	---	0.33	---	0.71	0.94
	Range	---	17.91-18.67	---	33.69-34.92	37.13-39.01

OH-58

Flight Condition		R.U.	T.O.	C	T	F.A.
ROUTINE	Mean	9.67	9.06	9.19	---	9.32
	S.D.	3.12	2.95	3.03	---	1.80
	Range	6.30-19.67	7.31-18.96	5.13-16.22	---	7.56-12.83

AH-1G

Flight Condition		R.U.	T.O.	C	T	F.A.
NOE	Mean	---	15.97	15.17	14.49	15.73
	S.D.	---	3.39	5.38	4.72	2.06
	Range	---	12.23-18.84	11.37-18.98	10.89-19.14	13.34-17.08

NOTE: R.U. = Run-Up
T.O. = Take Off
C = Cruise
T = Threat
F.A. = Final Approach
S.D. = Standard Deviation

The US Army aviator's perception of his aircraft is reflected in his IMV. The phase of flight evaluated produces a wide range of response from the baseline IMV. Fixed wing aircraft (U-21 and C-7) studied during routine flight operations indicate takeoff and final approach for landing are the periods of greatest stress or workload. This finding is in consonance with that of the USAF and USN.[1] The IMV obtained exceeded the current US military design standard of 13.12 LPM NTPD for oxygen systems during the final approach.[2]

During rotary wing flight, the two primary variables affecting IMV are the type helicopter and mission profile. Figure 1 illustrates the data in graphic format. The AH-1G Cobra gunship is perceived as a "constant" threat under the NOE flight profile. The IMV remains an approximate constant of 15 LPM NTPD throughout all phases of flight.

The OH-58 and UH-1H during a routine flight profile demonstrate an essentially stable IMV at expected levels of 9 to 11 LPM NTPD. The Army aviator exposed to the threat and workload of NOE, NNOE or NVD profiles demonstrates significant increase in his IMV. During NOE and NNOE in

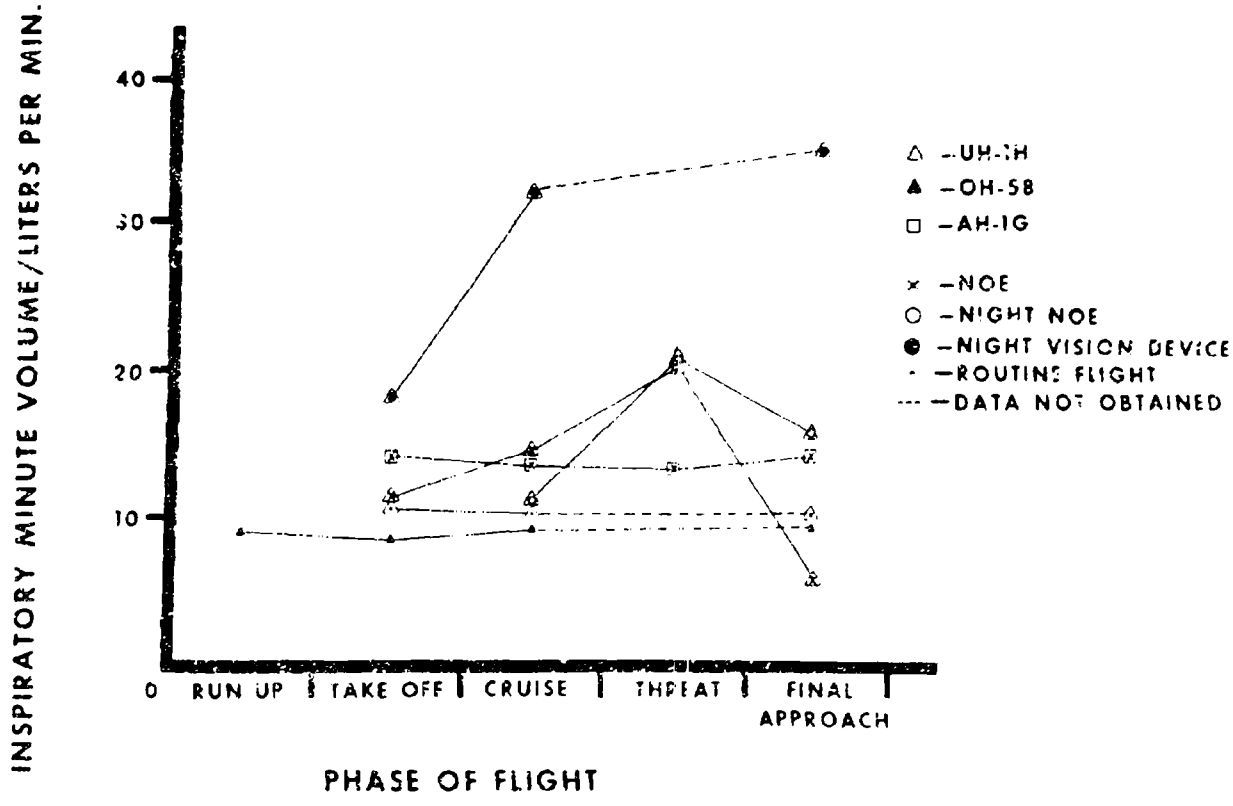
INSPIRATORY MINUTE VOLUME/LITERS PER MIN.
40
30
20
10
0
RUN UP
TAKE OFF
CRUISE
THREAT
FINAL APPROACH
PHASE OF FLIGHT
△ –UH-1H
▲ –OH-58
□ –AH-1G
× –NOE
○ –NIGHT NOE
● –NIGHT VISION DEVICE
· –ROUTINE FLIGHT
--- –DATA NOT OBTAINED

Figure 1

the UH-1H, the IMV is increased twofold. The use of the NVD in the UH-1H provides extreme values for IMV throughout the flight profiles. A threefold increase (35 LPM NTPD) occurs in cruise and final approach phase while using the NVD.

Interestingly, the final approach phase of day NOE in the UH-1H is viewed as a release from threat or stress as evidenced by a decrease in IMV to less than baseline levels. With use of the NVD, final approach is perceived as an extreme stress as indicated by the threefold increase. This finding supports the use of in-flight IMV determinations to differentiate aircrew workload from workload and stress/threat conditions.

The values of IMV obtained under the increased stress of NOE, NNOE and NVD far exceed the current oxygen design standards. Comparison of the mean values of 20 to 38 LPM NTPD (22.5 to 42.6 LPM BTPS) obtained in this study to the USN standard of 23.7 LPM BTPS and the USAF value of 25.1 LPM BTPS demonstrates the limitations of present US military oxygen design standards.[3,4]

The IMV values provide the initial estimate of the level of aircrew stress involved in current helicopter operations.

CONCLUSIONS

Stress of helicopter operations under the advanced operational concepts of nap-of-the-earth, night nap-of-the-earth flight, and the use of night vision devices has been evaluated by the use of inspiratory minute volume determinations. The IMV obtained during NOE, NNOE and NVD is increased threefold demonstrating the aviator's perception of the increased stress and/or threat. The IMV data obtained in the routine flight of US Army fixed wing aircraft is consistent with the USAF and USN data documenting the stress and increased workload during takeoff and landing. Use of IMV is considered a valuable tool in the clinical assessment of aircrew stress and workload. Study of IMV in conjunction with dynamic electrocardiography is ongoing to provide the research data base for helicopter stress/workload evaluation.

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